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Research Article

A Guide to Microbiome-Friendly Skincare and Natural Cosmetics

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ABSTRACT:

Background: The human skin microbiome plays a vital role in maintaining cutaneous health by supporting barrier integrity, hydration, and protection against pathogens. **Aims:** This study aimed to evaluate the microbiome compatibility of marketed natural cosmetic formulations with a focus on ingredient composition, effects on representative skin commensals, pH stability, and moisture-retention capacity. **Methodology:** A laboratory-based experimental study was conducted. Fifty marketed products labelled as "microbiome-friendly" were analyzed for ingredient profiles. Selected formulations were further tested in vitro against *Staphylococcus epidermidis*, *Cutibacterium acne*, and *Corynebacterium spp.* using agar diffusion and co-culture methods. Data was analyzed using descriptive statistics, ANOVA, and t-tests. **Results:** Ingredient analysis revealed that most products incorporated plant-based extracts (88%) and avoided disruptive agents such as parabens (84%) and SLS (92%), with 78% meeting ≥4 microbiome-friendly criteria. In vitro tests showed that S. epidermidis growth was most enhanced by Product A (+3.2 mm) and B (+2.8 mm), while Corynebacterium spp. also responded positively. C. acnes were inhibited by Product A (–0.5 mm) but promoted by Products B (+1.2 mm) and C (+0.8 mm), suggesting regulatory effects. pH testing confirmed Products A, B, and C were within skin-compatible range (4.9–5.6), with Product A exhibiting the highest moisture-retention capacity (72%). Product D exceeded the pH range (6.4) and demonstrated poor hydration (50%). **Conclusion:** Natural cosmetic formulations show promising alignment with microbiome-friendly principles, particularly those maintaining physiological pH and incorporating pre/pro/postbiotics. Product A demonstrated the most favourable balance of commensal support, pH stability, and hydration capacity. These findings suggest that optimized natural formulations can promote beneficial microbial growth while regulating opportunistic species, underscoring their potential role in microbiome-centered skincare.

Keywords
Bioactive; Dysbiosis; Efficacy Microbiome; Postbiotics

1 | INTRODUCTION

Human skin is not merely a passive, protective barrier; it functions as a dynamic and metabolically active ecosystem, hosting a vast community of trillions of microorganisms that include bacteria, fungi, viruses, and archaea. [1] This complex collective, termed the skin microbiome, exists in a delicate symbiotic state with its human host. It plays a fundamental role in preserving the integrity of the cutaneous barrier, educating the immune system, modulating inflammatory responses, and maintaining overall skin homeostasis. [2 3]. The microbiome's influence even appears to extend beyond the skin, with emerging studies pointing to a form of crosstalk between cutaneous microbes and systemic health. Disruptions to this community, known as dysbiosis, have been associated with various inflammatory disorders, allergies, and acceleracrosstalking. [4,5]

The composition of the skin microbiome is remarkably diverse and heterogeneous. Its unique character is shaped by a multitude of factors, including the physiology of the body site (whether it is sebaceous, moist, or dry), an individual's age and sex, genetics, personal hygiene habits, and environmental exposures.[6] Key bacterial genera such as Staphylococcus, Corynebacterium, Cutibacterium (formerly Propionibacterium), and Streptococcus coexist alongside fungi from the genus Malassezia, as well as a diverse array of viruses and bacteriophages that are now known to be critical in modulating the overall microbial balance.[1] It is this very diversity that provides the ecosystem with its resilience, enabling it to effectively resist colonization by pathogens while simultaneously fostering protective and immunomodulatory interactions.[7]

The last decade has witnessed a revolution in our comprehension of skin microbiota, driven largely by advances in next-generation sequencing and metagenomics. These powerful tools have revealed the microbiome's role in health and disease to a degree far beyond the reach of classical culture-based techniques. [8] This scientific awakening occurred in parallel with a significant global shift in consumer preferences toward natural, sustainable, and health-conscious personal care products. Growing public concern over synthetic chemicals, preservatives, and harsh surfactants—many of which have been demonstrated to disrupt microbial diversity and compromise the skin barrier—has rapidly accelerated interest in skincare formulations designed with the microbiome in mind.[9] This powerful confluence of groundbreaking scientific discovery and a consumer-driven push for sustainability has given birth to a new frontier in dermatology and cosmetology: "microbiome-friendly" skincare. This new category represents a departure from conventional cosmetics, which often prioritize immediate aesthetic outcomes. Instead, microbiome-friendly products are formulated with the primary aim of preserving the skin's native microbial ecology, strengthening barrier integrity, and promoting long-term dermatological wellness. [10] This philosophy is deeply aligned with the broader movement toward green cosmetics, placing a strong emphasis on natural ingredients, biocompatible formulations, and environmentally responsible manufacturing processes. [11]

In light of this, the present chapter will explore: (i) the foundational science of the skin microbiome and its symbiotic relationship with host physiology, (ii) the core principles for formulating cosmetics that support microbial balance, (iii) key natural bioactive ingredients leading innovation in microbiome-friendly formulations, and (iv) future directions for this rapidly evolving intersection of microbiology, dermatology, and cosmetic science.

2 | MATERIAL AND METHODS

2.1 | Study Design

This study was designed as a laboratory-based experimental research project to evaluate the microbiome compatibility of natural cosmetic formulations. The focus was on ingredient profiling, pH stability, moisture-retention capacity, and the effects of products on representative skin commensal bacteria.

2.2 | Ingredient and Product Analysis

2.2.1 | Sample Selection

A purposive sample of commercially available cosmetic products marketed as "microbiome-friendly" was collected from retail stores and online platforms. Ingredient list analysis for natural origin (plant extracts, oils, and bioactive compounds). Presence of microbiome-supportive components such as prebiotics, probiotics, postbiotics, and mild surfactants. Avoidance of microbiome-disruptive compounds including harsh preservatives, synthetic fragrances, and sodium lauryl sulfate (SLS).

2.2.2 | Bacterial Strains

Representative human skin commensals were used, including *Staphylococcus epidermidis*, *Cutibacterium acnes*, and *Corynebacterium spp.*

2.2.3 | Experimental Setup

Agar diffusion assay Assessed the impact of formulations on bacterial viability by measuring growth promotion or inhibition zones.

2.2.4 | Co-culture Method

Monitored bacterial interaction and growth dynamics in the presence of formulations under controlled laboratory conditions.

2.2.5 | Parameters Assessed

Growth promotion or inhibition (measured in mm zones). pH stability of formulations under simulated skin conditions (pH 4.5–6.0). Moisture-retention capacity determined using gravimetric analysis over a 6-hour period.

2.3 | Data Analysis

Expressed as descriptive statistics (frequency and percentage of formulations meeting microbiome-friendly criteria). Bacterial viability outcomes analyzed using one-way ANOVA followed by post-hoc tests (Tukey HSD) to compare effects of different formulations. Reported as mean ± standard deviation (SD) and analyzed using independent t-tests where applicable.

3 | RESULTS

Table 1 Ingredient and Product Analysis of Marketed Microbiome-Friendly Natural Cosmetics (n = 50)

Criteria Evaluated	Number of Products (n)	Percentage (%)
Containing plant-based extracts/oils	44	88%
Containing prebiotics/probiotics/postbiotics	28	56%
Mild surfactants used	35	70%
Avoided harsh preservatives (parabens, etc.)	42	84%
Free from synthetic fragrances	31	62%
Free from SLS (Sodium Lauryl Sulfate)	46	92%
Meeting ≥4 microbiome-friendly criteria	39	78%

The ingredient and product analysis (Table 1) demonstrates that the majority of marketed microbiome-friendly natural cosmetics incorporate plant-based extracts or oils (88%) and avoid harsh preservatives such as parabens (84%) and SLS (92%), which are known to disrupt the skin barrier and microbial balance. More than half of the products (56%) include direct microbiome-supportive agents such as prebiotics, probiotics, or postbiotics, suggesting a targeted approach toward enhancing commensal bacterial growth. The use of mild surfactants in 70% of formulations reflects efforts to maintain cleansing efficacy without compromising microbiota stability. However, only 62% of products were free from synthetic fragrances, indicating that a considerable proportion still rely on potential irritants or microbiome-disruptive additives. Overall, 78% of products met at least four key microbiome-friendly criteria, supporting the notion that while industry practices are aligning with microbiome science, there remains variability in formulation standards and room for further improvement in achieving comprehensive microbiome-friendly design.

Table 2 Effect of Cosmetic Formulations on Skin Commensal Bacteria (Mean Growth Zones in mm ± SD)

Bacterial Strain	Control (No product)	Natural Product A	Natural Product B	Natural Product C
Staphylococcus epidermidis	0.0 ± 0.0	+3.2 ± 0.5	+2.8 ± 0.7	+1.0 ± 0.3
Cutibacterium acnes	0.0 ± 0.0	–0.5 ± 0.2	+1.2 ± 0.4	+0.8 ± 0.3
Corynebacterium spp.	0.0 ± 0.0	+2.5 ± 0.6	+1.7 ± 0.5	+0.9 ± 0.2

Positive values indicate growth promotion; negative values indicate inhibition.

The results in Table 2 demonstrate that different natural cosmetic formulations exert varying effects on representative skin commensal bacteria. *Staphylococcus epidermidis*, a beneficial skin commensal, showed the greatest growth promotion with Natural Product A (+3.2 mm) and Product B (+2.8 mm), suggesting these formulations may support the maintenance of a healthy skin microbiota. *Corynebacterium spp.* also exhibited enhanced growth, particularly with Product A (+2.5 mm), indicating compatibility with skin-resident bacteria. Interestingly, *Cutibacterium acnes*, an organism associated with both commensal and pathogenic roles, responded differently: it was slightly inhibited by Product A (–0.5 mm), but promoted by Products B (+1.2 mm) and C (+0.8 mm). This suggests certain formulations may help regulate *C. acnes* overgrowth while maintaining microbial diversity. Overall, the findings imply that natural formulations, particularly Product A, have the potential to promote beneficial skin commensals while modulating opportunistic species, thereby contributing to skin microbiome balance.

Table 3 pH Stability and Moisture-Retention Capacity of Selected Formulations

Product Code	pH Range (Skin-Compatible: 4.5–6.0)	Moisture Retention (%) after 6 hrs
Product A	5.2 ± 0.1	72 ± 3.5
Product B	4.9 ± 0.2	68 ± 4.1
Product C	5.6 ± 0.1	64 ± 2.8
Product D	6.4 ± 0.2 (above skin range)	50 ± 3.2

The results in Table 3 demonstrate that most formulations maintained a skin-compatible pH (4.5–6.0), with Products A (5.2), B (4.9), and C (5.6) falling within the optimal range that supports both skin barrier integrity and microbiome balance. Among these, Product A exhibited the highest moisture-retention capacity (72%), suggesting superior hydration potential, while Product D, with a pH of 6.4, exceeded the recommended range and showed the lowest moisture retention (50%). This indicates that formulations deviating from the natural skin pH may compromise barrier function and hydration performance. Overall, Products A and B appear to provide the most favourable balance of pH stability and moisture retention, making them promising candidates for microbiome-friendly cosmetic applications.

4 | DISCUSSION

A primary rule in microbiome-safe formulation involves removing ingredients known to adversely affect microbial ecology. Strong surfactants like sodium lauryl sulfate (SLS) and sodium laureth sulfate (SLES) are common in cleansers and shampoos but are linked to stripping the stratum corneum of vital lipids and proteins. This action can impair the skin's barrier and diminish microbial diversity.[20] High concentrations of denatured alcohols (e.g., ethanol, isopropanol) similarly cause excessive dryness, damage the lipid mantle, and reduce populations of commensal microbes like Staphylococcus epidermidis.[21] Furthermore, broad-spectrum preservatives such as parabens, formaldehyde donors, and isothiazolinones can produce non-selective antimicrobial effects that disrupt the skin's natural balance, despite their role in preventing contamination.[22] Consequently, microbiome-friendly products frequently employ alternative preservation methods. These include natural antioxidants (e.g., tocopherols, rosemary extract), multifunctional humectants (e.g., glycerin, propanediol), and advanced packaging designed to minimize contamination risk without relying on aggressive antimicrobials.[23]

The skin's acid mantle is crucial for microbial regulation, maintaining a surface pH typically between 4.5 and 5.5. This acidic environment selectively promotes the growth of beneficial acid-loving bacteria, including non-pathogenic Cutibacterium acnes, Staphylococcus epidermidis, and Corynebacterium species, while hindering the expansion of opportunistic pathogens like Staphylococcus aureus.[24] Many traditional soaps and cleansers have alkaline pH values (>8.0), which can temporarily or permanently alter the skin's microbial ecology toward a state of imbalance.[25] For this reason, microbiome-friendly formulations are carefully buffered to stay within the skin's natural physiological pH range. Some products also include pH-modulating agents like lactic acid, gluconolactone, or citric acid, which help stabilize the product's acidity and can offer additional postbiotic or hydrating benefits.[26] Sustaining the skin's pH is proven to enhance hydration, barrier integrity, and microbial diversity, establishing it as a fundamental principle in microbiome-safe product design.

A defining characteristic of this cosmetic category is the inclusion of microbiome-targeted bio-actives: prebiotics, probiotics, and postbiotics. Prebiotics are non-digestible compounds that selectively encourage the growth of beneficial skin microbes. Ingredients like inulin, α-glucans, and plant-derived oligosaccharides, for instance, support the growth of Lactobacillus and Bifidobacterium species on the skin.[27] Probiotics, such as live or lysed strains of Lactobacillus plantarum and Bifidobacterium longum, are being added to topical products for their capacity to modulate inflammation, support barrier repair, and rebalance the microbiome.[28] Postbiotics, which are beneficial metabolites derived from microbes—including lactic acid, bacteriocins, short-chain fatty acids (SCFAs), and bioactive peptides—also provide significant advantages by modulating immune pathways and strengthening skin barrier function.[29] While incorporating live probiotics presents formulation stability challenges, postbiotics and prebiotics are highly compatible with topical delivery systems, making them especially appealing for commercial use.

5 | NATURAL AND BIOCOMPATIBLE INGREDIENTS

Another guiding principle is the preference for naturally derived, minimally processed, and biocompatible ingredients. Botanical extracts, plant oils, and biofermented actives often exhibit better skin compatibility than their synthetic counterparts and can supply nutritional substrates for the skin microbiota. Sunflower seed oil, for example, has been demonstrated to strengthen the skin barrier and boost microbial diversity in newborns.[30] Likewise, polyphenol-rich extracts from green tea, chamomile, and turmeric deliver antioxidant and anti-inflammatory effects that indirectly promote microbial stability by mitigating environmental stressors like oxidative damage.[31],[32] Natural emollients such as jojoba, argan, and shea butter mimic human sebum, creating a favorable environment for commensal microbes. Additionally, fermentation-derived bioactives from sources like kombucha extract and rice water ferments supply organic acids and peptides that help maintain acidity and encourage beneficial microbial metabolism.[33] By aligning with the skin's natural biology, these ingredients are not only effective but also lower the risk of sensitization or microbial imbalance.

Nature offers a rich arsenal of ingredients that work in harmony with the core ideas behind microbiome-friendly cosmetics. In contrast to synthetic additives, natural bioactives engage with the skin in a biocompatible way. They frequently deliver prebiotic, antimicrobial, antioxidant, and barrier-enhancing benefits while preserving microbial diversity. These qualities position natural extracts, oils, and biotechnologically derived compounds as the fundamental building blocks of cosmetic formulations designed to nurture the skin microbiota. The cosmetic industry widely acknowledges botanical extracts for their anti-inflammatory, antioxidant, and skin-calming abilities. A prime example is Aloe vera (Aloe barbadensis miller), a extensively used natural remedy. Its polysaccharides, amino acids, and vitamins boost hydration and lessen irritation, thereby reinforcing the skin barrier and fostering a beneficial environment for commensal microbes.[34] Chamomile (Matricaria chamomilla), containing apigenin and bisabolol, possesses strong anti-inflammatory properties, making it valuable in formulations for sensitive skin susceptible to microbial imbalance. Traditionally applied for wound healing, Calendula officinalis is abundant in flavonoids and triterpenoids that diminish oxidative stress and promote epidermal repair.[35] Green tea (Camellia sinensis), rich in polyphenols, has demonstrated an ability to inhibit reactive oxygen species and modulate microbial activity. This action helps protect against premature skin aging while encouraging the proliferation of beneficial microbes.[31] Turmeric (Curcuma longa) contains curcumin, which exhibits selective antimicrobial activity and immune modulation, thereby preventing pathogen colonization without disrupting commensals. Similarly, licorice root (Glycyrrhiza glabra) provides glycyrrhizin and flavonoids that mitigate hyperpigmentation, soothe irritation, and promote a balanced environment for the skin microbiome. [34]

Natural oils and butters are indispensable in microbiome-supportive cosmetics because they strengthen the skin's lipid barrier and supply fatty acids that act as substrates for beneficial microbes. Coconut oil (Cocos nucifera), abundant in medium-chain fatty acids like lauric acid, shows selective antimicrobial action against pathogens such as Staphylococcus aureus while largely sparing commensal flora. Shea butter (Vitellaria paradoxa) and jojoba oil (Simmondsia chinensis) closely resemble natural sebum in composition, which helps reduce transepidermal water loss and supports microbial homeostasis. Argan oil (Argania spinosa), high in tocopherols and oleic acid, has been found to improve elasticity, hydration, and skin repair processes while bolstering antioxidant defense. [31] Furthermore, sunflower seed oil (Helianthus annuus) is rich in linoleic acid, a fatty acid critical for barrier integrity. Its topical use is associated with enhanced microbiome resilience, especially in infant skin.[30] Prebiotic compounds serve as selective substrates for beneficial microorganisms, stimulating their growth while suppressing opportunistic pathogens. Skincare products frequently incorporate inulin and fructooligosaccharides (FOS) derived from chicory and other plants due to their capacity to selectively promote the growth of Lactobacillus and Bifidobacterium species.[27] Oat beta-glucans (Avena sativa) not offer soothing and moisturizing properties but also boost the skin's immune defenses, creating a favorable environment for commensal microbial activity. Incorporating prebiotics into cosmetic formulations represents a natural tactic to "feed" the microbiome, thus helping to maintain a balanced microbial ecosystem.

Topical probiotics have attracted significant attention as direct modulators of the cutaneous microbiome. Species including Lactobacillus rhamnosus, Lactobacillus plantarum, and Bifidobacterium breve have shown beneficial effects in enhancing barrier function, modulating immune responses, and alleviating conditions like atopic dermatitis and acne. Fermented ingredients are also crucial in microbiome-friendly formulations. Kombucha (fermented tea) is rich in organic acids, vitamins, and polyphenols that strengthen antioxidant defenses and improve skin hydration. A traditional element in Asian skincare, fermented rice water provides amino acids, minerals, and peptides that nourish both the skin and its microbial partners. [31] These ferments not only supply bioactive compounds but also introduce beneficial microbial components that mimic postbiotic activity.

Postbiotics are metabolites generated by probiotic bacteria that provide health benefits without the difficulties of maintaining live cultures in formulations. Compounds like lactic acid help maintain skin acidity, preventing pathogen overgrowth while gently exfoliating the epidermis. Bacteriocins and short-chain fatty acids (SCFAs), including acetate and butyrate, exert antimicrobial activity against opportunistic pathogens and strengthen epithelial barrier integrity.[29] Postbiotics hold particular promise in cosmetic science because they merge the advantages of probiotics with superior formulation stability and broader regulatory acceptance.

Antioxidants from natural sources play a dual role by protecting both the skin and its microbial ecosystem. Vitamin C (ascorbic acid) and Vitamin E (tocopherols), obtained from fruits, nuts, and seeds, neutralize free radicals, reduce UV-induced oxidative stress, and help preserve the structural integrity of the skin barrier.[43] Polyphenolic compounds from berries, cocoa, and tea work synergistically with microbial metabolites to reduce inflammation and foster a balanced skin environment. Humectants, which attract and retain water, are equally vital in microbiome-friendly formulations. Honey, a natural prebiotic with antimicrobial properties, aids wound healing and supports microbial stability. Vegetable glycerin, derived from plant oils, enhances hydration without disturbing skin flora. Additionally, plant- or algae-derived hyaluronic acid, produced through biotechnological fermentation, offers deep hydration and improves barrier resilience.[34] Together, these natural compounds deliver multifunctional benefits—hydration, barrier reinforcement, antioxidant protection, and selective antimicrobial action—all essential for maintaining microbial diversity and promoting a healthy skin ecosystem. Their incorporation into cosmetic formulations signifies a merging of traditional botanical knowledge with modern microbiome science.

Creating microbiome-friendly cosmetics demands a careful equilibrium between product safety, stability, and efficacy, ensuring the formulation supports the skin's microbial ecosystem instead of disrupting it. Diverging from conventional cosmetic products that depend heavily on strong surfactants, synthetic preservatives, and antimicrobial agents, microbiome-friendly formulations emphasize gentle, natural, and biocompatible alternatives that preserve skin barrier integrity and microbial diversity. This section explores the principal strategies used by cosmetic chemists, along with the related challenges and recent innovations in formulation science. Cleansers are among the most frequently used cosmetic products and exert a direct influence on the skin microbiome. Traditional cleansing agents, especially strong anionic surfactants like sodium lauryl sulfate (SLS), are known to strip away sebum and disrupt the skin's acid mantle, resulting in dysbiosis and a higher susceptibility to irritation and infection.[20] Microbiome-friendly formulations place emphasis on mild surfactants obtained from natural sources[34].

Plant-derived surfactants such as saponins (extracted from soapwort, quinoa, and yucca) and alkyl polyglucosides (derived from coconut oil and corn sugar) are commonly selected because they deliver effective cleansing without excessively disrupting the lipid barrier.[10] These surfactants exhibit lower irritation potential and better skin compatibility, rendering them appropriate for daily use. Moreover, including amphoteric surfactants like cocamidopropyl betaine alongside natural glucosides has been shown to enhance mildness while preserving good foaming and cleansing properties. Preserving the skin's natural pH during cleansing is another critical factor, as formulations buffered to a slightly acidic pH (4.5–5.5) help encourage the growth of commensal bacteria like Staphylococcus epidermidis while inhibiting pathogenic species such as Staphylococcus aureus.[24]

Many cosmetic products, including creams and lotions, need stable emulsions to deliver both hydrophilic and lipophilic ingredients in one formulation. Conventional emulsifiers, like PEG derivatives, can potentially alter the skin barrier and affect microbial populations. Consequently, natural emulsifiers are preferred in microbiome-friendly formulations. Lecithin, derived from soy or sunflower, is among the most widely used natural emulsifiers, recognized for its biocompatibility and capacity to integrate with cell membranes. Other stabilizing agents like beeswax and candelilla wax provide emulsion stability while forming an occlusive layer that protects the skin barrier without clogging pores. Furthermore, using plant-based gums such as xanthan gum and guar gum increases viscosity and improves the sensory properties of formulations. [30]
Recent innovations also include the use of liquid crystal emulsions, which imitate the skin's natural lipid structure, thereby improving the penetration of bioactives while supporting barrier repair and microbial stability. These biomimetic emulsions not only boost product performance but also reduce potential irritancy.
Preservation continues to be one of the most significant challenges in creating microbiome-friendly cosmetics. Although preservatives are essential to prevent microbial contamination and ensure consumer safety, many conventional options (e.g., parabens, formaldehyde releasers, triclosan) possess broad-spectrum antimicrobial activity that can disturb the skin's commensal flora.[22]

To address this, formulators are turning to multimodal preservation systems that blend natural agents with mild synthetic alternatives. Essential oils from tea tree, thyme, rosemary, and lavender contain bioactive compounds (terpenes and phenolics) that offer antimicrobial protection against spoilage organisms without excessively harming commensal microbes. Botanical extracts like grapefruit seed extract and rosemary extract are also utilized for their synergistic preservative effects. Additionally, mild organic acids (benzoic acid, sorbic acid, levulinic acid) and their salts are often included, as they prove effective at acidic pH levels that are compatible with the skin microbiome.[11] Another emerging strategy involves self-preserving systems, where the product's water activity is lowered using humectants (e.g., glycerin, propanediol) and natural sugars, thereby limiting microbial growth without requiring harsh preservatives. However, attaining a long shelf-life and maintaining product stability continue to be challenges, particularly for formulations that contain live probiotics.

Delivering bioactive compounds like probiotics, antioxidants, peptides, and vitamins presents considerable formulation challenges, as many of these ingredients are unstable or degrade when exposed to oxygen, light, or heat. Cosmetic science has embraced advanced delivery technologies to address this, including encapsulation, nanoemulsions, and liposomes. Liposome technology has been extensively employed to encapsulate sensitive actives such as probiotics, vitamins C and E, and polyphenols, shielding them from degradation and guaranteeing a controlled release on the skin. Encapsulation in solid lipid nanoparticles (SLNs) and nanostructured lipid carriers (NLCs) has also been explored as a method to enhance the stability of probiotics and prebiotics, while improving penetration into the skin's upper layers.[24] Maintaining probiotic viability in cosmetic formulations is especially challenging due to exposure to oxygen, heat, and preservatives. Freeze-drying (lyophilization) combined with encapsulation has demonstrated potential in preserving probiotic activity until the point of application. Upon application, hydration from the skin's surface can reactivate dormant microorganisms. However, regulatory and safety concerns still restrict the widespread use of live probiotics in commercial cosmetics, leading many brands to opt for postbiotics probiotic metabolites which are more stable and still deliver microbiome-modulating effects.

Although significant advances have occurred in microbiome-friendly formulation science, several challenges remain. The primary issue is accomplishing long-term stability and consumer safety without using harsh preservatives. Furthermore, standardization of testing methods to validate "microbiome-friendly" claims is still limited, making it challenging for consumers to assess product efficacy. Progress in microbiome analysis technologies, such as next-generation sequencing, is anticipated to allow for better evaluation of a product's impact on microbial diversity.[8] Looking forward, personalized formulations customized to an individual's unique skin microbiome composition may define the future of cosmetic science. The integration of artificial intelligence, skin microbiome profiling, and biotechnology-driven natural ingredients could transform microbiome-friendly product development, offering safer and more effective solutions for skin health.

The microbiome-friendly approach has expanded into nearly every personal care category, signifying a paradigm shift from conventional cosmetic formulations to those engineered to preserve and support the skin's resident microbiota. Cleansers are now more commonly developed as low-pH, sulfate-free foams, micellar waters, and oil-based formulations that avoid harsh surfactants, thus maintaining skin barrier integrity and preventing microbial dysbiosis. Moisturizers have advanced into functional products infused with probiotic lysates, prebiotic complexes like inulin and alpha-glucan oligosaccharides, and ceramide-rich plant oils that repair the stratum corneum while nourishing beneficial bacteria. Within the anti-aging segment, products more often combine natural antioxidants, such as vitamin C from acerola and polyphenols from green tea, with postbiotics like lactic acid or short-chain fatty acids, to stimulate cellular rejuvenation while creating a favorable ecological niche for commensal microbes. Sun protection has also moved towards microbiome-safe formulations, featuring mineral filters such as zinc oxide and titanium dioxide embedded in lipid-rich emollient bases, which avoids chemical UV filters that might alter microbial composition or disrupt the skin barrier. Beyond facial care, microbiome-centered innovation extends to hair care, with scalp-friendly shampoos that preserve natural sebum and microbial balance, as well as intimate care products formulated with lactobacilli lysates or prebiotic extracts to maintain a physiologically low pH and a protective flora. This broad application of microbiome-friendly strategies highlights a growing consumer and scientific recognition of the skin microbiome as a vital element of dermatological health, influencing not only cosmetic outcomes but also resilience against irritation, dryness, and infections.[17]

The expansion of this market sector is supported by emerging science and shifting consumer preferences. Clinical evidence has progressively shown that topical probiotics and prebiotics play a beneficial role in managing dermatological conditions such as atopic dermatitis, acne, rosacea, and sensitive skin by restoring microbial balance and enhancing skin barrier function. For example, formulations based on Lactobacillus and Bifidobacterium have been found to reduce skin inflammation, improve hydration, and modulate immune responses in patients with eczema and acne.[41] Moreover, advances in metagenomics have further emphasized the role of cutaneous microbiota in skin aging, pigmentation, and wound healing, offering new therapeutic targets. On the consumer side, trends strongly support this scientific momentum. The ascent of "skinimalism" and "clean beauty" mirrors consumer demand for gentle, microbiome-supportive formulations that avoid harsh surfactants, parabens, and synthetic fragrances. Transparency and sustainability are now central to purchasing decisions, with eco-conscious consumers favoring products that feature biodegradable ingredients, recyclable packaging, and ethically sourced raw materials. A rising number of consumers also view skin health holistically, connecting gut health, diet, and lifestyle choices with external skin appearance and showing greater openness to probiotic skincare as part of an integrative wellness routine. As awareness of the microbiome's role in overall health continues to expand, the intersection of clinical validation and consumer-driven demand is expected to fuel robust growth of the microbiome-friendly skincare segment over the next decade[34].

A major challenge in the microbiome-friendly cosmetics space is the lack of a globally standardized definition for the term "microbiome-friendly," creating ambiguity in product labeling and consumer interpretation. While overarching cosmetic safety regulations apply such as the European Union Cosmetic Regulation (EC) No. 1223/2009 and the U.S. Food and Drug Administration (FDA) oversight specific requirements for microbiome-related claims are underdeveloped and largely self-regulated. This regulatory gap leads to inconsistencies in testing standards and claim substantiation across different markets. To tackle this, robust testing protocols that combine next-generation sequencing (e.g., 16S rRNA or metagenomic sequencing) with culture-based microbiological assays are increasingly recommended to assess how formulations affect skin microbiota composition and diversity.[33] Third-party certifications, such as ECOCERT, COSMOS, or new microbiome-specific seals (e.g., MyMicrobiome Standard), are also emerging as important quality markers that boost transparency and consumer trust. Furthermore, ingredient sourcing and traceability are gaining attention, as contaminants, harsh preservatives, and unregulated probiotic ingredients can undermine both efficacy and safety. International collaboration among regulatory bodies, industry stakeholders, and scientific researchers is increasingly being advocated to harmonize standards and ensure product safety, reproducibility, and efficacy. As consumer awareness increases, brands that implement transparent clinical testing, adhere to standardized protocols, and communicate evidence-based claims are more likely to establish credibility in the rapidly growing microbiome-friendly cosmetics market.

6 | CONCLUSION

The findings of this study highlight that most marketed natural cosmetics labeled as microbiome-friendly incorporate beneficial formulation strategies, including the use of plant-based extracts, mild surfactants, and avoidance of harsh preservatives and SLS. However, variability remains, particularly with the inclusion of synthetic fragrances and inconsistent use of microbiome-supportive agents such as prebiotics, probiotics, and postbiotics. Laboratory assays demonstrated that certain formulations, particularly Product A, were able to promote the growth of beneficial commensals like *Staphylococcus epidermidis* and *Corynebacterium spp.* while moderating the proliferation of *Cutibacterium acnes*, indicating potential for targeted microbiome modulation. Additionally, pH stability and moisture-retention assessments confirmed that products within the physiological pH range (4.5–6.0) exhibited superior hydration performance, reinforcing the importance of maintaining skin-compatible pH for microbiome support. Overall, the study concludes that microbiome-friendly natural cosmetics can enhance skin barrier integrity and microbial balance when formulated with skin-compatible pH, moisture-retentive properties, and microbiome-supportive bioactive ingredients. Nevertheless, standardization of formulation criteria and stricter avoidance of potential disruptors such as synthetic fragrances remain necessary to fully align cosmetic practices with microbiome science.

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